T12.04-9977 - Multiple High-Fidelity Modeling Tools for Metal Additive Manufacturing Process Development

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Identification and Significance of Innovation

Additive manufacturing, AM, processes have attracted significant interest from NASA and the aerospace community because of their potential for cost-effective fabrication of intricate structures from aerospace metal alloys that challenge conventional fabrication methods. Despite the rapid commercialization of selective laser melting, SLM, there are gaps in process modeling and material property prediction that contribute to slow and costly process qualification and product certification. Development and qualification of a new process requires a time consuming trial-and-error based optimization, available metal precursors are limited, and there can be significant variation in the quality of finished products. High-fidelity simulations offer a means to address the gaps between AM potential and effective use of the technology by complementing the limited in-situ diagnostics, helping to identify sources of variability, and enabling development of fast models for process control.

High-Fidelity Modeling for Metal AM Process Development and Optimization
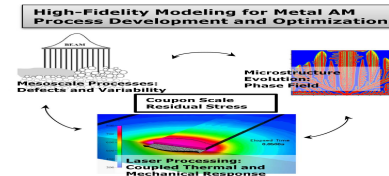
Estimated TRL at beginning and end of contract: (Begin: 2 End: 3)

Technical Objectives and Work Plan

The overall technical objective of the Phase I effort is to develop and demonstrate computationally efficient, high-fidelity simulation tools that address key phases of SLM processes. Specific objectives are:

?Develop prototype simulation codes for efficient, high-fidelity simulation of the SLM build process addressing thermal history, residual stresses, and part distortion; melt pool dynamics and impacts of metal powder size distribution on microstructural defects; and metal alloy microstructures resulting from the process;
?Verify the tools and perform preliminary validation against experimental characterization;
?Evaluate feasibility of applying these tools for SLM processing of 1 cm scale test coupons; and
?Identify improvements necessary to provide the needed high-fidelity, efficient SLM simulation tools.

To meet these objectives, the team will
?Develop, verify, and evaluate a thermomechanical simulator for SLM processing utilizing solution adaptive meshing technology;
?Develop, verify, and demonstrate a high-fidelity simulation capability for melt pool physics;
?Develop, parameterize, and validate phase field model simulations to

NASA Applications

NASA has demonstrated the potential for cost and time savings via additive manufacturing, successfully building and testing a complex rocket injector. The build took 3 weeks, at half the cost of traditional methods that require 6 months. The technology also offers the potential for design flexibility, weight savings, and increased reliability from monolithic parts. The proposed models will support confident, effective use of this technology for components for NASA systems.

Non-NASA Applications

Mature AM technologies will benefit designers and producers of aerospace components for military and civilian aircraft as they benefit NASA, enabling low 'buy-to-fly' costs and increased functionality. Beyond the aerospace industry, there are opportunities for this technology in other high-value engineering applications such as patient-specific production of biocompatible implants.

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NON-PROPRIETARY DATA